

Small-Scale Morphology in the Nearshore

Edith L. Gallagher and Edward B. Thornton

Oceanography Department Code OC

Naval Postgraduate School

833 Dyer Rd, RM 328

Monterey, CA 93943-5122

phone: (831) 656-2379 fax: (831) 656-2712 email: egallagh@oc.nps.navy.mil

Award #: N0001400WR20257

<http://www.oc.nps.navy.mil/~thornton>

<http://www.frf.usace.army.mil/SandyDuck/SandyDuck.stm>

<http://www.geog.uu.nl/fg/coast3d/fall1998.html>

LONG TERM GOAL

The long-term goal is to understand small-scale morphology (i.e. megaripples, ripples, bumps and holes, etc) in the nearshore. These dynamic features act as significant roughness elements and therefore contribute to wave dissipation, current generation and sediment transport.

SCIENTIFIC OBJECTIVES

The objectives are to establish a relationship between hydrodynamic and sediment conditions and the state of the seafloor. Large bedforms (with heights of 10-50 cm and lengths of 1-5 m) have been observed in many nearshore environments. However, few studies have quantified them and most observations have been under relatively mild conditions. As a result they are not accounted for in models which predict wave energy dissipation, nearshore currents or sediment transport.

Understanding the spatial distribution and the temporal variability of bedforms in the nearshore will allow more accurate parameterizations (of friction coefficients, efficiency factors, pick-up functions, etc) to be employed in nearshore models.

APPROACH

Bedforms were measured during two large-scale, multi-institutional experiments: SandyDuck at Duck, NC in Sep-Oct 1997 and COAST3D at Egmond aan Zee, The Netherlands in Oct-Nov 1998.

Measurements were made using a lagged array of seven sonar altimeters mounted on amphibious surveying vehicles (ASVs: the CRAB at Duck and the WESP at Egmond). The CRAB and the WESP, (with footprints of about 5 and 8 m, respectively) measure the large-scale morphology, but can not resolve the bedforms of interest. The altimeters (with a footprint of about 6 cm and sampled at 48 Hz), coupled with pitch, roll, yaw, and position measurements of the ASVs, produce detailed information about the bed state. During both experiments, surveys of the large-scale morphology were done approximately daily over a 500 x 700 m area at Duck and a 700 x 1000 m area at Egmond. An example from Duck of a cross shore profile from a single altimeter is shown in Figure 1a and a small section of bedforms from the trough is expanded in Figure 1b.

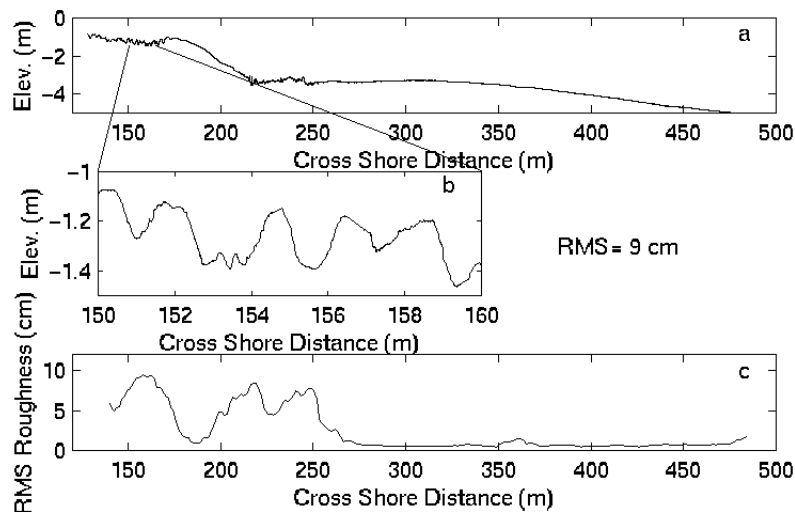


Figure 1. *a) Example of a cross-shore profile from a single sonar altimeter with large bedforms in the trough ($x=130-175\text{m}$). b) Example of a 10 m-long piece of Fig 1a (cross-shore location $x=150-160\text{ m}$). These data are demeaned and the root-mean-square is calculated to give the RMS roughness, which for this section of large bedforms is 9 cm and corresponds to the value at $x=155\text{ m}$ in Fig 1c. c) RMS roughness vs. cross-shore location. The RMS is calculated of overlapping 10 m-long sections (as in 1b) to produce this RMS roughness profile from the depth profile in Fig 1a.*

In addition to the altimeters, side-scan sonars were deployed during both experiments. In Duck, Tom Drake made measurements using a dual-frequency (100 MHz and 500 MHz) digital sidescan sonar (measuring 50 m-wide swaths) and during Egmond a small 675 kHz side scan sonar (measuring 10 m-wide swaths) was used. Measurements of the flow field and of sediment distributions were made by collaborators (S. Elgar, R.T. Guza, Bill Birkemeier and the FRF staff among others at Duck and the University of Plymouth, Utrecht University, Jean Lanckneus, Rijkswaterstaat and many more at Egmond.) Tim Stanton, here at NPS, made significant contributions of both time and equipment to this project.

WORK COMPLETED

The Duck experiment, completed in Oct 1997, resulted in 28 high-quality surveys with altimeters from about 6 weeks of daily CRAB surveys. The Egmond experiment was completed in Nov 1998 and owing to conflicting tasks for the WESP and a potentially devastating loss of equipment (from which it took about 2 weeks to recover), only 8 high-quality surveys with altimeters were obtained during the 6 week-long experiment. Post-processing for both experiments is now complete. Examination of spatial and temporal variability of bed roughness at Duck and its dependence on mobility number (a non-dimensional measure of the local flow and sediment conditions) is complete and is being prepared for publication. Bed roughness data from Egmond are now being compared with mobility number estimates as well as with roughness data from Duck. In addition, the Duck side scan sonar data are being combined with altimeter data to give a complete 3-D view of bedforms.

RESULTS

Using RMS roughness of 10 m-long sections of the seafloor (Figure 1) the magnitude and extent of bedform fields can be mapped over the whole survey area for each experiment. At Duck, it has been found that RMS roughness is highest inside the surfzone, in the trough of the sand bar. However, the spatial and temporal variability of this pattern is high. Daily roughness maps were averaged in the alongshore to give a daily average cross-shore profile of RMS bed roughness. The standard deviation of the alongshore average represents the spatial variability. These daily average cross-shore profiles were averaged in time to give a general cross-shore profile of roughness for the whole experiment, the standard deviation of which, represents the temporal variation of bedforms (Figure 2). These averaged estimates of roughness can be used to guide modellers in using spatially (and temporally) varying bed roughness values.

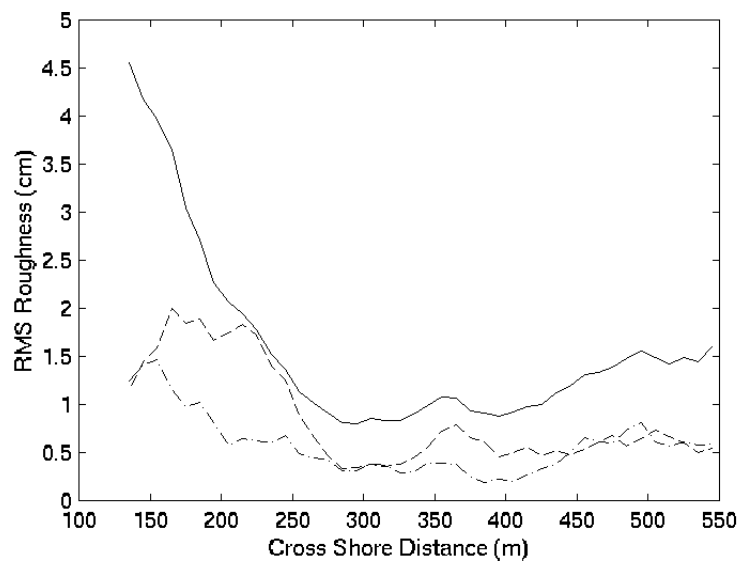


Figure 2. Time-average, alongshore-average RMS bed roughness vs. cross-shore distance (solid line). The dash-dot line is standard deviation of the time average and represents the temporal variability. The dashed line is the mean of the daily alongshore standard deviation and represents the mean spatial variability.

Comparing the mean roughness profile (solid line, Fig 2) with the typical bathymetric profile in Figure 1a, roughness is seen to increase steadily as the water depth decreases over the inner bar. The observed spatial and temporal variations in bed roughness are hypothesized to depend on local flow conditions and sediment properties, which change significantly over this region. Thus roughness measurements made near fixed current meters were compared with mobility numbers calculated from the measured currents (Figure 3). RMS roughness values are low (~ 1 cm) for mobility numbers greater than about 100. This suggests that the bed is planed off (ie, sheet flow conditions) or has small ripples below the resolution of the altimeters (about 1 cm RMS). The bedforms are also small for small mobility numbers (< 30). For mobility numbers between 30 and 100, a wide range of roughness values can occur suggesting that both ripples and megaripples can occur under these conditions.

Similar analyses are being done on the Egmond data. Because the beach at Egmond has multiple bars, a lower slope and shorter period waves (among other factors), the cross shore pattern of bedform distribution is quite different from that at Duck. Comparisons between the two beaches are being made.

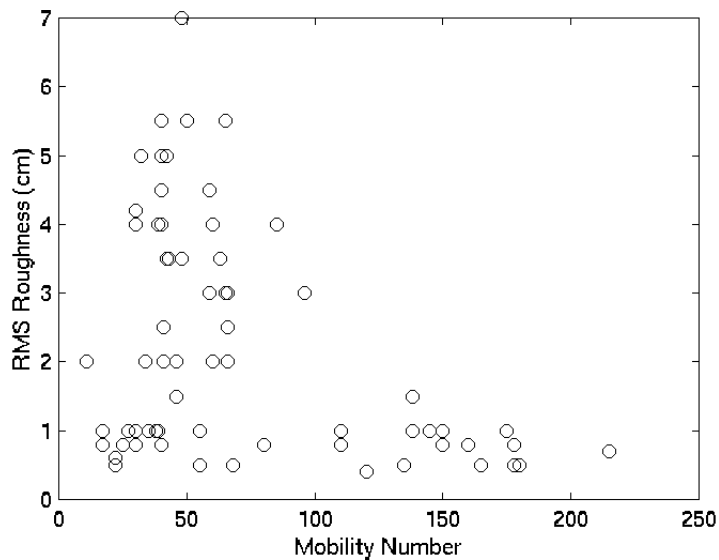


Figure 3. RMS bed roughness vs. mobility number calculated from measured currents (generally within about 10 m of the roughness measurement). Mobility number is calculated from combined waves and currents and from sediment measurements that were made twice during the 6 week-long experiment at Duck.

IMPACT/APPLICATIONS

Large bedforms in the surf zone are ubiquitous. The possible effects of these features on nearshore hydrodynamics and sediment transport are many: their migration is a vehicle for sediment transport and a mechanisms for burial of objects, turbulence generated in their lee can suspend sediment and transport momentum vertically, increased roughness over them alters significantly boundary layers, drag coefficients and therefore wave and current energy dissipation. However, they are not accounted for in any models of hydrodynamics or sediment transport.

In this study, new and novel observations of the distribution of large bedforms in the nearshore and their variability are being documented. Further work will focus on prediction of large bedforms and their effects on sediment transport and hydrodynamics. It is hoped that this work will be directly applicable to improving nearshore hydrodynamics and sediment transport models.

RELATED PROJECTS

Altimeter measurements from Duck are being compared with side scan data collected by Tom Drake and students at North Carolina State University.

Altimeter measurements from Duck are being compared with video measurements of (what is thought to be) the surface signature of bedforms in shallow water by Rob Holman and students at Oregon State University.

Altimeter measurements from Egmond will be compared with measurements of bedforms made from the moveable sled CRIS by Leo Van Rijn and Bart Grasmeier at TU Delft.

Boundary layer measurements made by Stanton at Duck will be compared with altimeter measurements for information about effects of bedforms on boundary layers.